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Observing the planet formation time-scale by ground-based direct imaging of planetary companions to young nearby stars: Gemini/*Hōkūpa'a* image of TWA-5

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Abstract. Many extra-solar planets and a few planetary systems have been found indirectly by small periodic radial velocity variations around old nearby stars. The orbital characteristics of most of them are different from the planets in our solar system. Hence, planet formation theories have to be revised. Therefore, observational constraints regarding young planets would be very valuable. We have started a ground-based direct imaging search for giant planets in orbit around young nearby stars. Here, we will motivate the sample selection and will present our direct imaging observation of the very low-mass (15 to 40 Jupiter masses) brown dwarf companion TWA-5 B in orbit around the nearby young star TWA-5 A, recently obtained with the 36-element curvature-sensing AO instrument *Hōkūpa'a* of the University of Hawai'i at the 8.3m Gemini-North telescope on Mauna Kea. We could achieve a FWHM of 64 mas and 25 % Strehl. We find significance evidence for orbital motion of B around A.

1. Introduction: Direct imaging search for giant planets

So far, no direct imaging detection of an extra-solar planet in orbit around a star has been achieved, mainly because of the problem of dynamic range: Planets are too faint and too close to their bright primary stars. Neither speckle techniques nor space-based observations have been able to directly detect a planet around another star. From radial velocity observations, it is known, though, that planets and even planetary systems do exist around other stars. One can avoid the problem of dynamic range by observing young nearby stars, where there could be young planets still contracting and accreting, so that they are relatively hot and (self-)luminous, e.g. Burrows et al. (1997).

A well-suited sample for such a program is the TW Hya association (TWA) of a few dozen young ($\sim$ 10 Myr) low-mass pre-main sequence (i.e. T Tauri)

stars at a distance of roughly 55 pc (e.g. Webb et al. 1999). Several members of TWA have been observed by the HST NICMOS, where two planet candidates and one brown dwarf companion candidate were detected: A planet candidate near TWA-7 (9.5 mag fainter than the star in H and K at a separation of 2.5 arc sec) was also detected by H- and K-band speckle from the ground (Neuhäuser et al. 2000a); an H-band spectrum taken with ISAAC at the VLT has shown that it is a background K-type star (Neuhäuser et al. 2001). The planet candidate near TWA-6 has not yet been confirmed nor rejected, it is 12 mag fainter than the star in H at a separation of 2.5 arc sec (Schneider et al. 2001). The brown dwarf companion candidate 2 arc sec north of TWA-5 (presented first by Lowrance et al. 1999 and Webb et al. 1999, and also observed by Weintraub et al. 2000), has been confirmed by both proper motion and spectroscopy (spectral type M9) by ground-based optical and IR follow-up imaging and spectroscopy using FORS2 and ISAAC at the VLT (Neuhäuser et al. 2000b); simultaneously and independently, also Schneider et al. (2001) took a spectrum of this object and confirmed the spectral type first published by Neuhäuser et al. (2000b) using an HST STIS spectrum with smaller wavelength range.

The brown dwarf companion TWA-5 B has a mass of 15 to 40 Jupiter masses (according to different theoretical tracks and isochrones), an age of 12 ± 6 Myrs (as TWA-5 A), and it is the 4th brown dwarf companion in orbit around a normal star confirmed by both spectrum and proper motion. It is the one with the lowest mass, possibly only slightly above the deuterium burning mass limit. It is also the first one in orbit around a pre-main sequence star and the first one in orbit around a spectroscopic binary: TWA-5 A is a single- or possibly double-lined SB T Tauri star (Torres et al. 2001).

2. Gemini *Hōkūpa′a* observation of TWA-5

We observed several TWA members with the University of Hawai'i (UH) 36-element curvature-sensing Adaptive Optics (AO) instrument *Hōkūpa′a* at the 8.3m Gemini-North on Mauna Kea, Hawai'i, in UH pay-back time in February 2001. TWA-5 was observed in the photometric night 23/24 Feb 2001 at sub-arc sec seing condition. We observed the object with the Wollaston, the dual-imaging polarimeter, in order to detect a possible circumstellar disk around the star (Potter et al., in prep.). As usual with *Hōkūpa′a*, we used the UH IR camera QUIRC. Individual exposure times were 6 seconds, obtained at different positions and rotations on the chip. After dark and sky subtraction and flat fielding, we shifted and co-added all frames to the final image with 8 min total exposure (fig. 1). We could achieve a FWHM of 64 mas and 25 % Strehl.

From the similar brightness of the two SB components of TWA-5 A in high-resolution spectra, both stars of the SB are of simliar spectral type, hence both are early M-type stars, like the type in (spatially unresolved) spectra of TWA-5 A. The SB orbit has not been solved, yet. If the elongation seen in the saturated part of TWA-5 A in figure 1 is due to these two stars, then their separation of roughly 50 to 100 mas would correspond to a ~ 10 year orbit at 55 pc, consistent with the radial velocity variation seen since a few years. It may well be possible within a few years to determine the masses of both components dynamically, namely by simultaneous solutions for the astrometric and spectroscopic orbit.

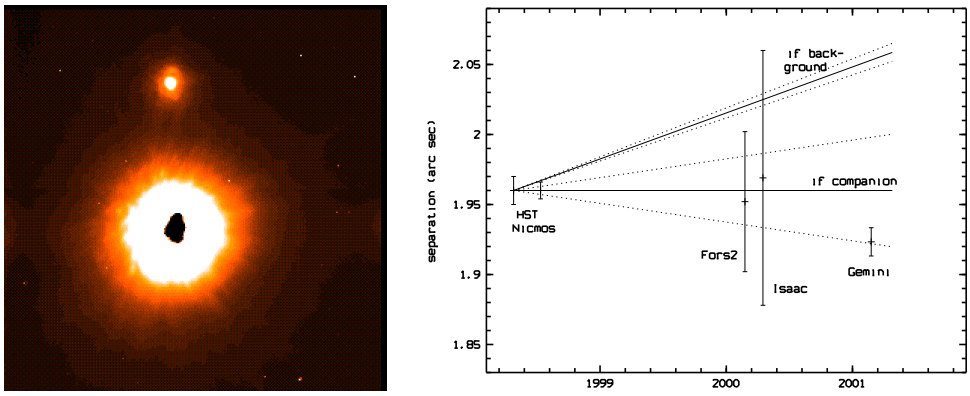

Figure 1. left: *Hōkūpa′a*/QUIRC H-band image of the faint brown dwarf TWA-5 B (64 mas FWHM) two arc sec north of the bright TWA-5 A (with saturated center elongated by 40 mas). right: Change in separation between A and B from 1998 to 2001, not consistent with B being a non-moving background object (proper motion of A is known from Tycho), but with B being a companion (dotted lines allow for orbital motion, see Neuhäuser et al. 2000b).

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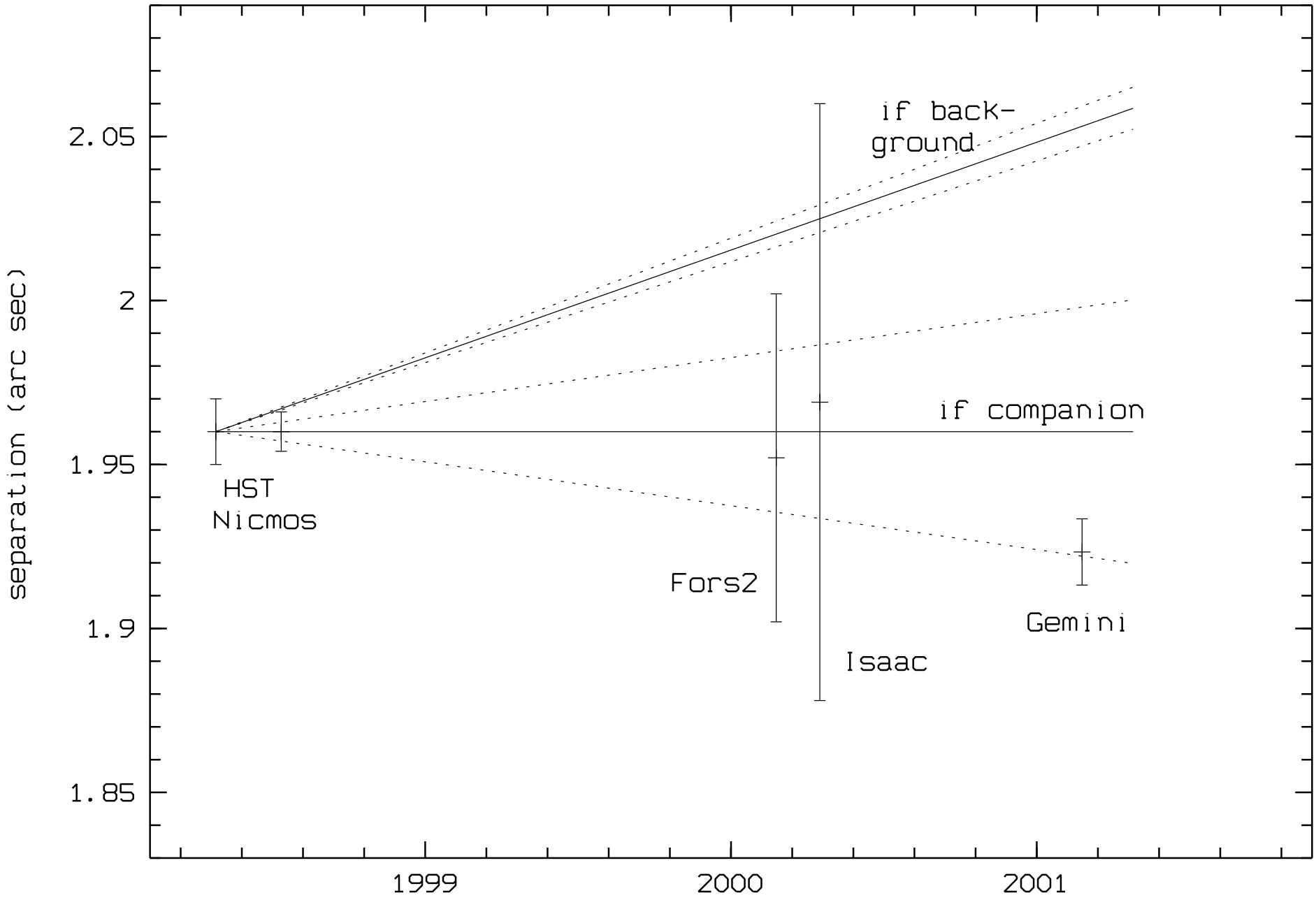
separation (arc sec)
2.05
2
1.95
1.9
1.85
1999
2000
2001
if back-
ground
if companion
HST
Nicmos
Fors2
Isaac
Gemini